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Theory and Modeling of Wake Fields Generated by Relativistic Electron Beams in Long Accelerator Structures *

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As a charge bunch passes a perturbation in an accelerator structure an electromagnetic wake field is generated which can re-interact with the charged particle beam. This process can lead to degradation in the quality of the beam, or worse, can lead to beam breakup instabilities. A substantial amount of work in the analysis of short induction linac accelerator cavities has been done using the $2\frac{1}{2}$ - D finite-difference time-domain (FDTD), code AMOS for the calculation of the wake potentials and characteristic wake impedances of such structures. We are extending these type of calculations to more general 3-D accelerator structures that are typically many wavelengths long, in contrast to the localized wake fields generated in short accelerator gaps. While AMOS allows various multipole mode distributions to be launched, the geometry of the structure must be cylindrically symmetric. We use TSAR, a 3-D FDTD code to model more general 3-D accelerator structures and excitations. To simulate a propagating charge bunch a series of point current sources are distributed within the accelerator structure phased such that the speed of propagation is that of the electron beam. The resultant electromagnetic fields are then decomposed into various multipoles along the accelerator structure. The coefficients of each multipole are then decomposed temporally and spatially (along the accelerator structure) using a 2-D Laplace-Fourier transform to determine the Green's function for the structure. The complex multipole modal coefficients $A_m(\omega, k_z)$ can be used to advance a test charge moving behind the source using the Lorentz force equations to determine the effect of the wake field on the overall quality of the electron beam. A set of full 3-D calculations for the rotationally symmetric accelerator cavity are performed with TSAR to check results with the AMOS code. The use of TSAR and resulting post-processing computations are demonstrated on a 3-D structure similar to a stripline beam-position monitor.

Keywords: wake field, electromagnetic modeling, accelerator, electron beam

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